HYDROELECTRIC PLANT
ON MISSISSIPPI RIVER, MOLINE, ILLINOIS

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DESIGN OF HYDROELECTRIC PLANT

-on-

MISSISSIPPI RIVER, MOLINE, ILLINOIS.

A Thesis Presented by:

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To

The President and Faculty

of

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For the Degree of

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Having completed the Prescribed Course in

Civil Engineering.

Chicago, Illinois.

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Alfred E. Phillips Prof. Civil Eng.

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L. C. Monin

INTRODUCTION.

In presenting this thesis for approval by the Faculty of the Civil and Electrical Engineering Department of the Armour Institute of Technology, it has been the aim of the students to carry out as nearly as possible, present practice in the design of hydro-electric power stations.

Standard practice has been closely adhered to wherever possible, no attempt being made at original design in such things as machine parts and electrical equipment. All other designs, however, have been made according to the students' best knowledge.

It is not the intention of the students to present a complete and detailed design of the installation, but merely such a design as would prove of great use in promoting such a development and showing the feasibility of the project.

INDEX.

LIST OF DRAWINGS.

THE GENERAL PROBLEM.

In general the developement will consist of a dam across the river which may also be made to act as a spillway by raising vertical gates, a shore dam or retaining section, a power house and ship locks. The problem which presents itself is to determine the amount of power which can be economically developed. To do this, we must resort to government data, whereby we may determine the maximum and minimum stream flow and the available head and base our calculations accordingly.

The ship locks must be made according to government specifications, and as time does not permit we will not attempt to do anything with this branch of the project.

LOCATION OF SITE.

The proposed development is situated on the Mississippi River about seven miles north of Rock Island, Illinois, and six miles north of Davenport, Iowa, the distances being measured along the river. Part of the electric power developed is intended to be used for manufactur-

ing purposes in these towns and part is to be transmitted by high voltage to neighboring towns.

The advantages for construction and other purposes are excellent. The C.R.I.& P. R.R. and the C.M. & ST. P. R.R. run within a short distance of the site, and the C.R.I. & N.W. R.R. runs along the river bank. These railroads afford convenient means of communication with Moline and Rock Island and present ample means for transportation purposes. The river itself also presents excellent and cheap means for transporting construction materials.

SOURCE OF POWER AND STREAM MEASUREMENTS.

The source of power for this development lies in the fall of the river between Le Claire, Iowa, which is at the head of the rapids, and Rock Island Bridge at the foot of the rapids. From the head of the rapids to the site of the proposed dam the low water fall is 10.77 feet and the high water fall 8.67 feet. The low water elevation was assumed to be raised to Elev.

576.144 by building the dam thus giving a head of sixteen feet.

The period of lowest flow which occurred in 1864 shows that the discharge of the river at this point was 17,000 cubic feet per second, and the maximum discharge recorded is 250,000. second feet.

Government readings of the daily gage height at Rock Island, Illinois, for forty years are available, from which the stream flow could be calculated for every day. These gage readings, however, are too costly for our purpose, and it was decided to obtain only the readings for the lowest water year which are given on pages

A profile of the river at Rock Island was not available, so a cross-section of the river further up, giving approximately the same area and wetted perimeter, was used. Assuming that the velocity and discharge in this section were the same as those at Rock Island for minimum and maximum discharges, the water surface was given the same gage reading as those taken at Rock Is-

land. Other values for discharge were calculated by interpolation. From the above data we were able to plot a rating curve for the river at Rock Island where the zero of the gage reading, i,e. the lowest flow, corresponded to a discharge of 20,000 cubic feet per second. By changing the horizontal scale so as to read 17,000. instead of 20,000 the rating curve at the proposed site was obtained.

With the aid of the rating curve and the gage reading shown on pages 7-9 we were able to plot a hydrograph for the lowest water year at Rock Island. Then changing the vertical scales so as to read 17,000 instead of 20,000, a hydrograph of the river at the proposed site was obtained.

BACK WATER CALCULATIONS.

Assuming the river to be at the low water stage, the calculations for "C" in the formula:

$$C = \left(\frac{L}{Rh^{3/2}}\right)$$

were made in which the letters have the meaning as given below:

C = Coefficient depending on roughness of the channel.

V = Velocity at the section considered.

L = Length in feet between two sections.

h = Difference in elevation between two sections.

With 17,000 cubic feet flowing in the river, the coefficient "C" was determined for sixteen sections of the river. The average value of "C" thus determined was 50.

With the dam constructed and the elevation of the water surface raised to elevation 576.34 feet, the height of the water surface at Le Claire was determined, the discharge being taken as 250,000 cubic feet per second. The elevation of the water surface at Le Claire was found to be 587.098 feet.

Le Claire would not be affected by the building of the dam, but Rapids City across the river would be flooded to a height of 3.198 feet above the high water mark. This matter could be taken care of by either building a small retaining wall or by compensating the riparian owners who sustain any damages.

GAGE READINGS AT ROCK ISLAND BRIDGE 1891.												
DATE	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
1.	1.0	1.0	3.4	6.9	10.1	3.15	3.0	1.3	0.5	0.05	1.0	1.6
2.	0.9	1.45	3.4	7.35	10.2	3.1	2.95	1.2	0.55	0.00	0.95	1.4
3.	1.5	2.3	3.3	7.6	10.3	3.0	2.9	1.2	0.6	0.05	0.85	0.7
4.	1.5	3.9	3.6	7.65	10.3	3.1	3.1	1.15	0.55	0.2	0.8	0.3
5.	1.35	5.6	3.3	7.65	10.3	3.15	3.2	1.2	0.5	0.2	0.8	0.1
6.	1.2	6.1	3.1	7.65	10.2	3.4	2.95	1.2	0.5	0.25	0.8	0.3
7.	1.1	5.55	2.8	7.75	10.0	3.4	3.1	1.1	0.45	0.35	0.7	0.25
8.	1.2	5.45	2.9	7.85	9.7	3.2	3.25	1.0	0.45	0.45	0.8	1.7
9.	1.3	4.9	2.6	7.9	9.5	3.1	3.4	1.0	0.4	0.6	0.85	2.3
10.	1.4	5.5	2.3	8.1	9.05	3.0	3.4	0.9	0.4	0.7	0.9	1.9
11.	1.2	7.0	2.1	8.35	8.7	2.85	3.2	0.9	9.35	0.75	0.9	1.65

GAGE READINGS (Continued)

12.	1.3	6.4	2.1	8.5	8.2	2.70	3.1	0.95	0.4	0.75	0.9	1.60
13.	1.7	5.5	1.8	8.65	7.7	2.60	2.9	0.95	0.4	0.75	0.75	1.75
14.	1.6	4.9	3.0	8.75	7.1	2.5	2.9	1.05	0.4	0.9	0.7	1.6
15.	1.3	4.2	2.7	8.75	6.55	2.4	2.8	1.0	0.35	1.1	0.6	1.4
16.	1.0	2.7	1.9	8.75	6.1	2.35	2.5	0.95	0.35	1.2	0.7	1.75
17.	1.2	2.4	1.75	8.85	5.6	2.3	2.35	0.85	0.35	1.2	0.9	1.9
18.	1.0	3.1	2.4	8.90	5.3	2.5	2.25	0.7	0.35	1.3	0.9	2.0
19.	1.0	4.4	3.1	8.95	4.9	2.5	2.15	0.75	0.3	1.3	1.0	1.85
20.	0.9	6.0	4.1	8.9	4.5	2.5	2.05	0.7	0.25	1.25	-0.4	1.7
21.	0.8	4.5	4.4	9.1	4.4	2.6	1.95	0.7	0.25	1.20	-0.15	1.6
22.	0.7	4.6	4.4	9.2	4.35	2.6	1.90	0.65	0.2	1.2	0.6	1.7
23.	0.5	5.0	4.6	9.25	4.2	2.7	1.8	0.6	0.15	1.1	0.85	2.1

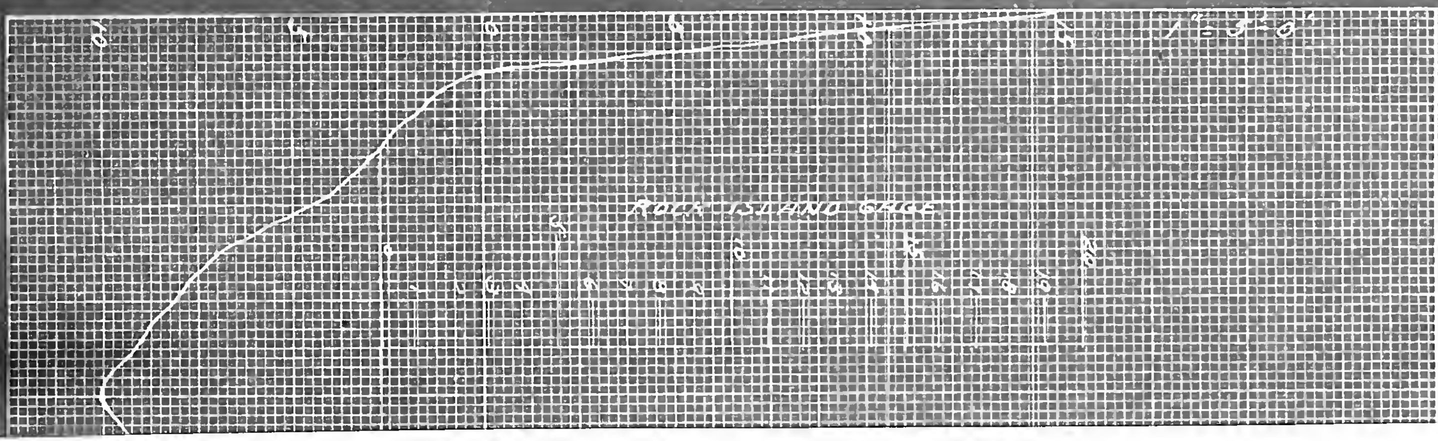
GAGE READINGS (Continued)

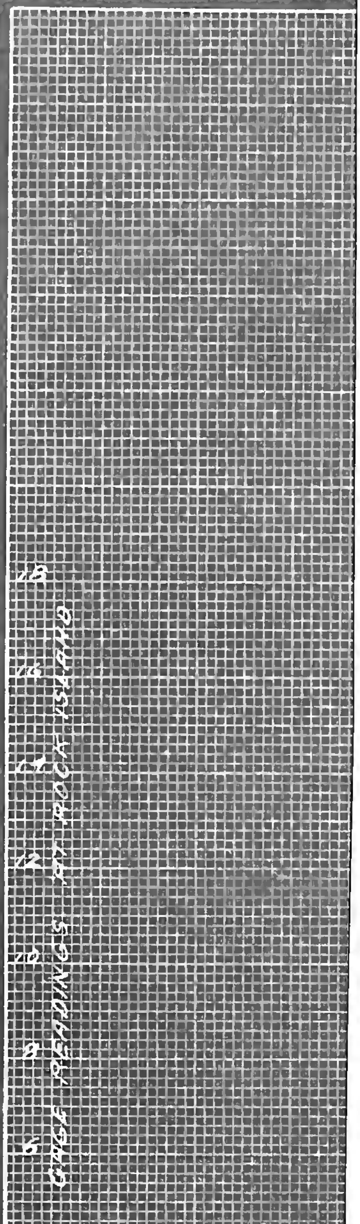
24.	0.95	3.5	7.0	9.25	4.2	2.7	1.75	0.55	0.15	1.05	0.7	2.75
25.	0.9	3.2	7.1	9.35	4.1	2.6	1.7	0.55	0.1	1.1	0.6	3.5
26.	0.7	3.55	6.9	9.35	4.0	2.7	1.6	0.5	0.1	1.1	0.45	3.3
27.	0.5	3.4	6.4	9.65	3.8	2.75	1.5	0.5	0.1	1.1	0.2	2.1
28.	0.45	3.7	5.8	9.9	3.6	2.9	1.4	0.5	0.1	1.05	0.2	1.55
29.	0.7		5.5	9.95	3.5	3.0	2.3	0.5	0.15	1.05	0.65	1.55
30.	0.6		5.4	10.05	3.4	3.0	1.25	0.5	0.1	1.05	2.00	1.60
31.	1.0		6.1		3.75		1.3	0.5		1.05		

The only available data on the discharge measurements of the Mississippi River at Rock Island are given on the following table:

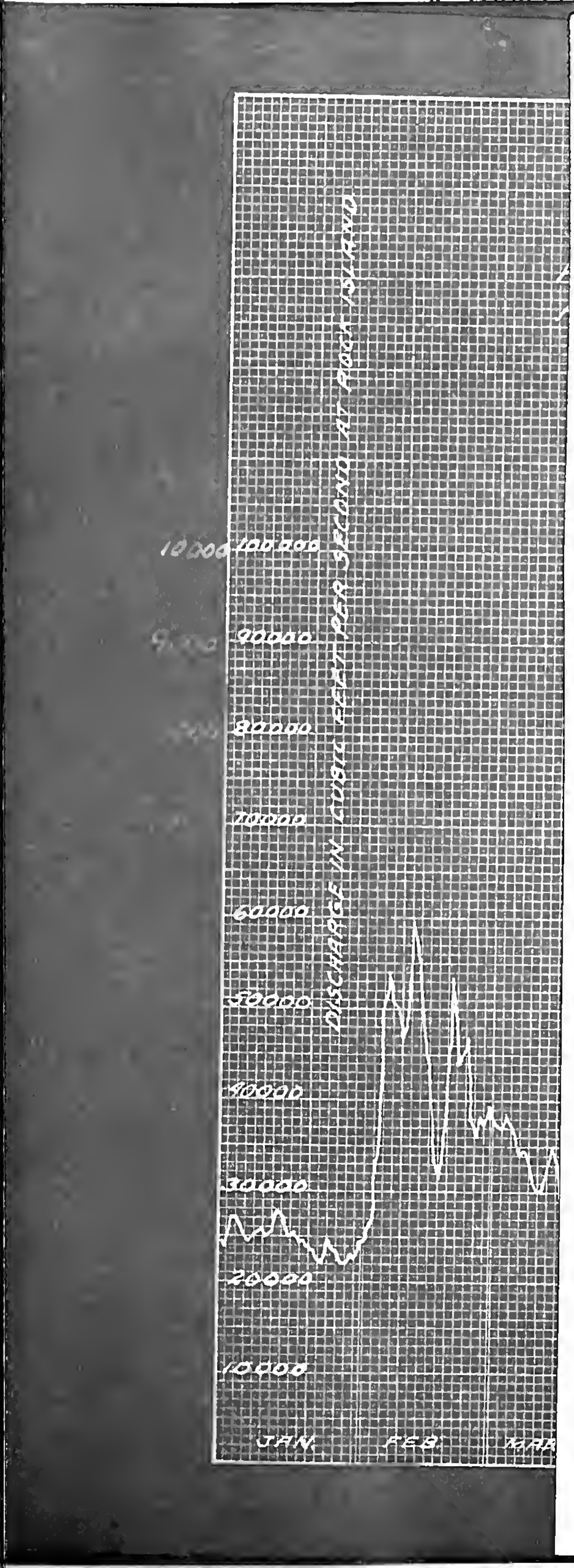
Location	Year.	Stage above L.W. Ft.	Width. ft.	Wetted perimiter. ft.	Area sq. ft.	Mean velocity per second ft.	Discharge per second. cu. ft.
Rock Island	1878	2.1	2,444	2,445	19,109	1,5860	30,313
do.	1880	18.4	2,737	2,740	60,880	4,3456	251,348

A cross-section of the river corresponding to the above data will be found on page .

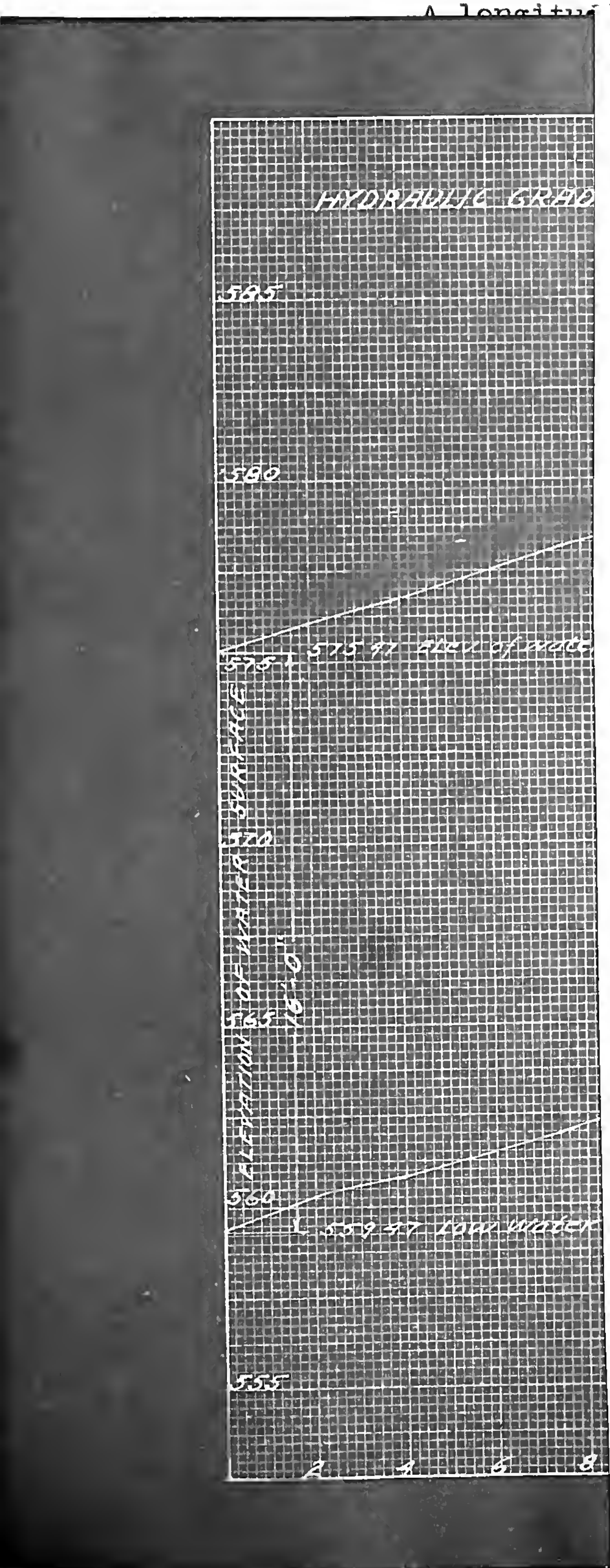

ROCK ISLAND GAGE


GAGE READINGS AT ROCK ISLAND
18
16
14
12
10
8
6
4
2
10
20
30

A longitud


DISCHARGE IN CUBIC FEET PER SECOND AT ROCK ISLAND
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
JAN.
FEB.

A longitu



585
580
575
570
565
560
555
ELEVATION OF WATER SURFACE
16'-0"
2
4
6
8

A longitudinal profile of the river showing the original and new water elevations caused by the dam is shown on page 14.

AVAILABLE POWER.

From a careful study of the hydrograph, it was thought inadvisable to base the calculations upon the minimum flow which only lasted thru a period of two days. A flow of 30,000 cubic feet per second may be relied upon for practically fifty per cent of the time, so this value was used with the assumption that a steam reserve could be depended upon during the dry periods.

The horse power available was calculated from the formula:

$$H.P. = \frac{qhEw}{550}$$

q = quantity of water in cu. ft. per sec.

h = head in feet.

E = Efficiency taken as 80%

w = weight of a cubic foot of water.

$$H.P. = \frac{30000 \times 16 \times .80 \times 62.5}{550} = 43,700 \text{ or}$$

say 45,000.

DESCRIPTION OF DAM.

The main dam from the Iowa side to the power house is designed to be 4625 feet long, of which 2975 feet is spillway in the present bed of the river and the remaining 1175 feet retaining shore dam. The spillway section of the dam is to consist of 119 arch spans, each twenty-five feet between piers four feet thick and an average height of thirty feet, forming a bridge eighteen feet wide on top. An Ogee shaped overfall will occupy the lower part of the space under each arch between the piers with a steel vertical lift gate resting on its crest to control the flow.

DESIGN OF DAM.

The maximum flood volume to be discharged is 280,000 cubic feet per second. Assuming that there will be 119 spillway sections, each section must discharge

$$\frac{280000}{119} = 2350 \text{ cubic feet per second.}$$

The length of the crest will be calculated from the formula:

$$L = \frac{Q}{C\ H^{3/2}}$$

Using a value of "C" equal to 3.33 and solving for L we get

$$L = \frac{2350}{3.33 \times 36.3} = 19.45 \text{ feet}$$

Because of the uncertainty in using the value of "C" it was deemed advisable to make L equal twenty-five feet. This will provide for a maximum discharge of

$$Q = 3.33 \times 25 \times 36.3 \times 119 = 359{,}000 \text{ cubic feet.}$$

of water per second or 28.2 per cent in excess of the required amount.

Diagrams showing the stresses in the dam with the reservoir empty and full are shown on drawings No. III. Stresses in the heel and toe were calculated from the formulas:

$$P = \frac{R \sin \alpha}{L}\left(1 \pm \frac{6e}{L}\right)$$

R = Resultant pressure on base.

L = Length of base.

e = Eccentricity.

α = Angle that the resultant makes with the base.

THE POWER HOUSE.

The power house which is located on the Illinois side, is 800 feet long, 109 feet wide and 123 feet high from the lowest point in the tail race to the highest point on the roof. It will contain twenty main turbine and generator units, and two smaller units.

The superstructure is built of reinforced concrete and contains three floors. The generators and transformers are located on the main floor. The second floor carries the oil-switches and the third the high tension bus-bars and the electrolytic lightning arresters.

The floors were designed as concrete slabs supported by steel I beams which rest either on concrete piers or are attached to pilasters. Triangle mesh reinforcement was used in the second and third floors.

The substructure is built almost entirely of concrete, steel being used only in two places, at the turbine bearing, and in the wall on the intake side of the power house.

The Intakes and Scroll Cases:

The water enters each turbine thru three intakes which unite in forming the scroll case, the intakes being made with a gradually decreasing cross-section from the entrance to the scroll case. The scroll case is moulded in the concrete around the turbine, and its cross-section also decreases uniformly, the rate of decrease being such that the same amount of water, and at the same velocity, will pass thru equal parts of the turbine circumference.

The Draft Tubes:

After passing thru the turbine the water enters the draft tube, which is circular and twelve feet in diameter immediately below the turbine. Each draft tube is forty feet long and in the first eight feet of its length the cross-section changes from a circular to an elliptical section then being maintained up to the tail race. The area keeps steadily increasing from the wheel to the tail race, the effect being to reduce the wheel discharge of 15.2 feet

per second to 4 feet per second at the end of the draft tube, and to increase the effective pressure of water on the turbines.

The Turbines:

There are twenty main turbines of the vertical shaft single runner type. Each turbine will develope 2500 H.P. under a sixteen foot head. The effective diameter of the turbine wheel is nine feet and it passes 1720 cubic feet of water per second under a sixteen foot head. Eighteen of the turbines are required to develop the rated output of the plant, two being kept as spare units and for use in times of high tail-water. The speed of the turbines is 56 r,p.m. To drive the exciters two small turbines are placed at the center of the power house. They are rated at 900 H.P. each, and under a sixteen foot head pass 573 cubic feet per second. All of the turbines are made by the Morgan Smith Co. To regulate the speed Lombard oil-pressure governors are used.

The Generators:

The generators are three phase, 25

cycle alternators, coupled directly to the turbines. They are built by the General Electric Co. and are of the revolving field type, having a rating of 1875 kva. at 11000 volts when operating at normal speed.

To excite the fields of the alternators and to furnish light to the station, two direct current, 500 KW. 110 volt generators are installed. If required, one of these machines is capable of supplying all of the excitation current needed by the alternators.

Other Electrical Apparatus.

The voltage of each alternator is stepped up from 11,000 to 70,000 volts by means of three single phase transformers. The transformers are each rated at 750 kva., and have both their primary and secondary sides connected in delta. The transformers are connected to the high-tension bus-bars thru 70,000 General Electric oil-switches, type H_6. The low tension sides of the transformers are connected to the alternators thru General Electric K_2 switches.

To protect the transmission lines and the electrical apparatus from damage due to lightning discharge, electrolytic lightning arresters, connected to the lines thru horn gaps, are installed. The horn gaps are provided with disconnecting switches to disconnect the arrester from the line whenever it is required to do so.

Roof Trusses:

The steel roof trusses, which are spaced ten feet apart and span over the entire width of the building, were designed and built by the Chicago Bridge Co. They support the roof which is covered with green tiles.

Crane:

To provide for the handling of the generators and turbines, a thirty ton crane, placed forty-three feet above the generator floor, is used, the power required to operate it being taken from the direct current buses.

DESIGN OF DAM.

Details of Design.

General Data:

The low water mark was taken at Elev. 560.34. By raising the water level sixteen feet at the dam the water surface will be at Elev. 576.34. The dam is so designed that the water surface will always be at the same level whether the river is discharging its maximum or minimum amount of water. Although the highest water level ever expected will only reach elevation 576.34, it was thought advisable to take 578.34 as a basis for the design. The top of the steel vertical lift-gates will be at Elev. 580.0.

These gates are to slide in vertical grooves in the concrete piers and are to be lifted and operated by a traveler of the wrecking-crane type, running on tracks upon the bridge.

Method of Design:

The dam will be designed in two separate sections as was done in the Keokuk project.

The pier will be assumed to take the dead load due to the weight of the arch bridge, the steel lift-gate when it is raised from the crest of the spillway, and the weight of the pier itself. It must also take any lateral pressure that the water may exert on the gates.

The overfall or spillway section, is sc designed that the area of the base is sufficiently large to take care of the entire shearing force due to the lateral pressure of the water, without transmitting any of it to the piers.

The dam will be investigated when the pond is empty and when it is full for the following conditions:-

Maximum stresses at the toe and heel.

Stability against overturning.

Shearing force on the base.

Design of the Piers: Reservoir empty.

For the preliminary design the piers were assumed to the four feet thick. The top of the bridge was made 6.66 feet above the high water mark making the elevation 585.0 or 33.5

feet above the river bed. Assuming the concrete to weigh 150 pounds per cubic foot, the weight of the pier is:

$$\frac{18 + 36}{2} \times 33.5 \times 4 \times 150 = 542{,}000 \text{ lbs.}$$

and the weight of the bridge

$$\frac{2 + 4}{2} \times 18 \times 19 \times 150 = 10{,}600 \text{ lbs.}$$

making a total of 552,600 lbs.

By taking moments about the heel of the dam the resultant force was found to act at a distance of 13.9 feet from the heel, giving an eccentricity of 4.1 feet. Using the formula given on page 8 the maximum stress in the heel and toe were found to be:

$$P = \frac{552600}{36 \times 4}\left(1 + \frac{6 \times 4.1}{36}\right) = 6512\# \text{ per sq.ft.}$$

$$P = \frac{552600}{36 \times 4}\left(1 - \frac{6 \times 4.1}{36}\right) = 2680\# \text{ per sq.ft.}$$

Design of Pier: Reservoir full.

The stresses in the abutment were next

calculated by assuming the level of the water in the pond to be at Elev. 578.34 and with the lift-gate resting on the crest of the spillway.

As before, the total dead load will be 552,600 lbs. acting at a distance of 13.9 feet from the heel of the dam.

The horizontal pressure on the gate due to the water was found to be:

$$\frac{687.5}{2} \times 11 \times 25 = 94{,}500\ \#$$

By combining these two forces graphically, the resultant pressure was found to be 560,000 lbs. with an eccentricity of three inches. The eccentricity in this case is so small that the pressure may be considered as being uniformly distributed over the base, making the pressure per square foot equal to

$$\frac{552{,}600}{36 \times 4} = 3870\ \#$$

Safety Against Overturning:

The only force tending to overturn the

dam will be the horizontal water pressure, and the force tending to hold it down is the weight of the part considered. These two forces acting at right angles to each other form couples upon which the stability of the structure is dependent.

The dam will tend to overturn about the toe, which is therefore taken as the center of moments. The overturning force is

$$94,500 \times 19 = 179,600 \text{ Ft. Lbs.}$$

The resisting force is

$$552,680 \times 22.1 = 12,180,00 \text{ Ft. Lbs.}$$

Factor of safety against overturning

$$\frac{12,180,000}{179,600} = 67.8$$

Shearing on the Base:

To prevent the dam from moving bodily down stream the entire base was embedded four feet below the river bed which is of blue limestone and able to withstand a bearing pressure

of thirty tons per square foot.

The force tending to shear off the base is the horizontal water pressure. This shearing force is resisted by the area of the pier at the base. The unit shearing force is them:

$$\frac{94500}{36 \times 4 \times 144} = 4.56 \,\# \text{ per sq. in.}$$

Design of Spillway, Pond Empty:

In determining the shape of the overfall it was decided to make the spillway conform as nearly as possible to the shape of a parabola. The equation of the parabola selected was

$$y = \sqrt{10\,x}$$

This equation did not give quite the form desired, but by broadening out the curve a little the desired results were obtained.

For the preliminary design the width of the base was taken as 29 feet and the height above the river bed as 15.5 feet. Considering a section one foot wide, the weight is approximately 46,000 lbs. acting at a distance of ten

feet from the heel of the dam. The steel gate was assumed to weigh 2000 lbs. making a total weight of 48,000 lbs.

With an eccentricity of 4.5 feet the pressure at the heel and toe were found to be

$$P = \frac{48,000}{29}\left(1 + \frac{6 \times 4.5}{29}\right) = 3200\# \text{ per sq.ft.}$$

$$P = \frac{48,000}{29}\left(1 - \frac{6 \times 4.5}{29}\right) = 150\# \text{ per sq.ft.}$$

Design of Spillway, Pond Full:

The dead load will be the same as before, 48,000 lbs. In addition to this we have for the vertical weight 2000# additional, due to the water on the crest, thus making a total of 50,000 lbs.

The horizontal water pressure is

$$\frac{62.5(33.5 - 15.42)\ 15.42}{2} = 15,600\#$$

Combining the above forces graphically, the resultant pressure was found to be 52,000 # with an eccentricity of eleven inches,

thus making the pressure at the heel and toe

$$P = \frac{50,000}{29}\left(1 + \frac{6 \times .833}{29}\right) = 3000\# \text{ per sq.ft.}$$

$$P = \frac{50,000}{29}\left(1 - \frac{6 \times .833}{29}\right) = 1452\# \text{ per sq.ft.}$$

Shear on Base:

The area to resist the shear is 29 x 1 = 29 sq. ft. making the shear per sq. in.

$$\frac{15600}{29 \times 144} = 3.73\ \#$$

Stability :

The overturning moment is

15,600 x 10.6 = 165,500 Ft. Lbs.

Resisting Moment:

50,000 x 19 = 950,000 Ft. Lbs.

Factor of Safety:

$$\frac{950,000}{165,500} = 5.26$$

THE POWER HOUSE.

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Detail Design.

Gallery Floor:

The gallery floor is designed to carry the lightning arresters, the high tension bus-bar compartments and the line compartments.

I beams support this floor every four feet in order to carry the load on this floor to the wall and to the posts. This floor, and the two floors below it, are 28 ft. 6 in. wide. The weight of each lightning arrester is 2750#, of the bus bar compartment 5912# and of the line compartment 10,800#.

These loads give a maximum bending moment of 662,400 in. lbs., and for a working stress of 16,000 lbs. per sq. in. in the steel I beam whose section modulus is

$$\frac{662,400}{16,000} = 42, \text{ needed.}$$

12 in. 40 lb. I beams have the requir-

ed section modulus and are used. They carry the 3.5 in floor slab on which the compartments and lightning arresters are placed.

As there is no wall to fasten these I beams to on the side nearest the generator room, they are fastened to other I beams, 20 ft. in length running lengthwise of the building between steel posts. The posts are 20 ft. apart and the I beams between them must support the load of four of the 12 in. 40 lbs. I beams.

The section modulus found for the 20 ft. I beams was 207, which gave 24"-105# I beams for the girders between posts.

Balcony Floor :

This floor is designed to carry the weight of the oil switches and line compartments. A concrete slab 4.5" thick was used, and I beams were placed under it every 4 feet, as in the floor above.

The weight from the oil switch which goes to one I beam was 11,340#, and the weight of the compartment 9180#. 18"-70# I beams are

needed for this floor between the wall and girders, the girders being 20"-85# I beams.

Transformer Floor:

On account of the depression in the floor for the tracks running along the building, the beams in the floor were not placed as in the other two floors, but lengthwise. This was done to avoid an excessive use of concrete for the floor slab.

The transformers weigh 12,935# each, and are placed 10 ft. apart. The area of the bottom of each transformer is 13.75 sq. ft., which gives 942.5 # per sq. ft. of floor. The bending moment due to this load is

$$\frac{1}{8} wl^2 = \frac{942.5 \times 3 \times 3 \times 12}{8} = 12{,}720 \text{ in.lbs.}$$

the beams which are to support the concrete slab being three feet apart.

The thickness of concrete required is

$$d = \sqrt{\frac{M}{R\ b}} = \frac{12720}{110 \times 12} = 9.65 \text{ in.}$$

The slab was made 10" thick and weighs 120# per sq. Ft.

Each beam supports a three foot width of slab = 360 # per ft.

$$B.M. = \frac{1}{8} wl^2 = \frac{360 \times 20 \times 20 \times 12}{8} = 130,000 \text{ in.lbs.}$$

When the transformers are moved, each beam will have to take half the weight of one transformer, and this must be considered.

This gives a bending moment of 388,000 in. lbs. which must be added to the 130,000 previously found. The I beams required to resist the total bending moment are 12"-31.5#

These are supported every ten feet by beams af, de, bg, etc., each of which carries the load of one transformer in one panel as afde. The members required for this load are 24"-80# I beams.

The beams between the 20 ft. posts, as de, must be carried on girders ab, bc, etc., ab carries one half the load from de, and the beams required are 18"-65# I beams.

Design of Racks:

The size of openings in the racks was made so that velocity of the water thru the racks was about 1.5 ft. per second. This would make each opening

$$\frac{1720}{1.5} = 1150 \text{ sq. ft.}$$

1720 cubic feet per second being the discharge of each turbine.

The racks were made thirty feet wide and forty feet long, the vertical height being thirty-eight feet. They consist of narrow bars of iron $\frac{1}{4}''$ x 3", spaced 2" apart resting on horizontal I beams spaced 5' apart, which in turn are supported by two heavy I beams at the sides of the opening. These two I beams, running parallel to the racks, must be designed to withstand the full head of water in case the racks should be choked up with leaves or other materials.

The total pressure which each beam would have to take is:

$$\frac{38}{2} \times 15 \times 40 \times 62.5 = 710,000 \text{ ft. lbs.}$$

This pressure acts at a distance of $\frac{38}{2}$ feet from the bottom, but was taken as uniformly distributed in order to simplify the calculations:

$$M = \frac{Wl^2}{8} = \frac{710,000 \times 12}{8} = 1,065,000 \text{ in.lbs.}$$

$$\frac{I}{C} = \frac{1,065,000}{16,000} = 73,$$ which corresponds

to the section modulus of a 15"-60# I beam.

The clear opening thru the racks is

$$38 \times \frac{7}{8} \times 30 = 1000 \text{ sq. ft.}$$

which gives a velocity of 1.72 ft. per second thru the racks.

GENERAL ESTIMATE OF COST.

The figures as given below are only approximate and were obtained by comparison with the costs of exsisting plants and other installations of which the actual costs were known.

The Electrical World of 1910 gives the cost of the generators as \$11.00 per Horse Power generated. Since the turbines deliver 450,000 Horse Power at the turbine shaft the cost of the generators will be

$$450,000 \times \$11.00 = \$495,000.$$

Gillette's hand book of cost data gives the cost of an 800 KW. step-up transformer as \$7500. Taking this as a basis, the cost per KW. would be

$$\frac{7500}{800} = \$9.48$$

Assuming that the generators have an efficiency of 95%, the total power to be transformed is:

450,000 x .95 = 42,750 K.W.

making the cost of the transformers,

42,750 x 9.48 = $406,000.

The cost of the exciter units was taken from data given by H.M. Hobart in the Standard Handbook, who gives the cost of a 1000 K.W. direct current generator as $10,500.

The oil switches of which there are twenty for generators and six for the out-going lines, may be obtained from the General Electric Co. at a cost of $1200. per switch, making the total cost

26 x 1200. = $33,200.

The lightning arresters may be also obtained from the same company at a cost of $1400. There will be six of these making the cost

1400 x 6 = $8400.

Data for the cost of the dam and power house was taken from Gillette's Handbook of Cost Data, in which the cost of a similar dam was giv-

en as $5.92 per cu. yd. which includes the cost of labor, concrete and form work.

The dam project will contain 61,500 cubic yards, making the cost

61,500 x $5.92 = $363,000.

The power house will contain 46,400 cubic yards, making the cost

46,400 x $5.92 = $274,000.

There will be a total of 85 miles of transmission line at approximately $5000. per mile making

5000 x 85 = $425,000.

Switch board and station wiring will cost 9/40 of the generator and transformer cost or

9/40 x 911,000 = $205,000.

The water wheels will have a cost of approximately 36.65/40 of the generator and transformers making

$\frac{36.65}{40}$ x 911000 = $752,000.

Allowing 10% for engineers charges and

10% for contingency charges, the total cost would be approximately $3,600,000.

TRANSMISSION LINE.

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Design of Peoria Line.

20,000 KW. are to be transmitted along this line to Peoria, Ill., a distance of seventy-five miles. Two circuits will be used, each of which will normally carry one half of the power. The voltage at the receiver is 65000 volts, which gives a voltage from line to neutral of 37,800 volts.

The assumed loss at full load, with all wires in use is 15%, which gives

$$\frac{20,000 \times 15}{600} = 500 \text{ KW. as the I R loss in one}$$

line.

The current per wire is :

$$\frac{10,000 \times 1000}{3 \times 65,000} = 89 \text{ amperes .}$$

The resistance per wire is :

$$\frac{500,000}{89 \times 89} = 62.4 \text{ ohms, or .16 ohms per 1000 ft.}$$

#2 solid copper wire, having a resistance of #1594 ohms per 1000 ft. was used. This gives an actual loss of

$$89 \times 89 \times .1594 \times 5.28 \times 75 = 500{,}000 \text{ watts per line.}$$

The towers are placed 600 feet apart, and the distance between the wires, which are placed at the corners of triangles, is nine feet.

The inductance of each wire is:

$$.1404 \log \frac{\delta}{r} + .01524 \text{ millihenries} = .1404$$

$$\log \frac{9 \times 12}{.129} + .01524 = .425 \text{ millihenries}$$

per 1000 ft.

The capacity to neutral is:

$$\frac{38.8 \times 10}{\log \frac{2D}{d}} = \frac{38.8 \times 10}{\log \frac{18 \times 12}{.258}} = 13.3 \times 10 \text{ farads}$$

per mile.

The inductance per wire is:

$$.425 \times 75 \times 5.28 = .167 \text{ henries} = L$$

The inductive reactance is:

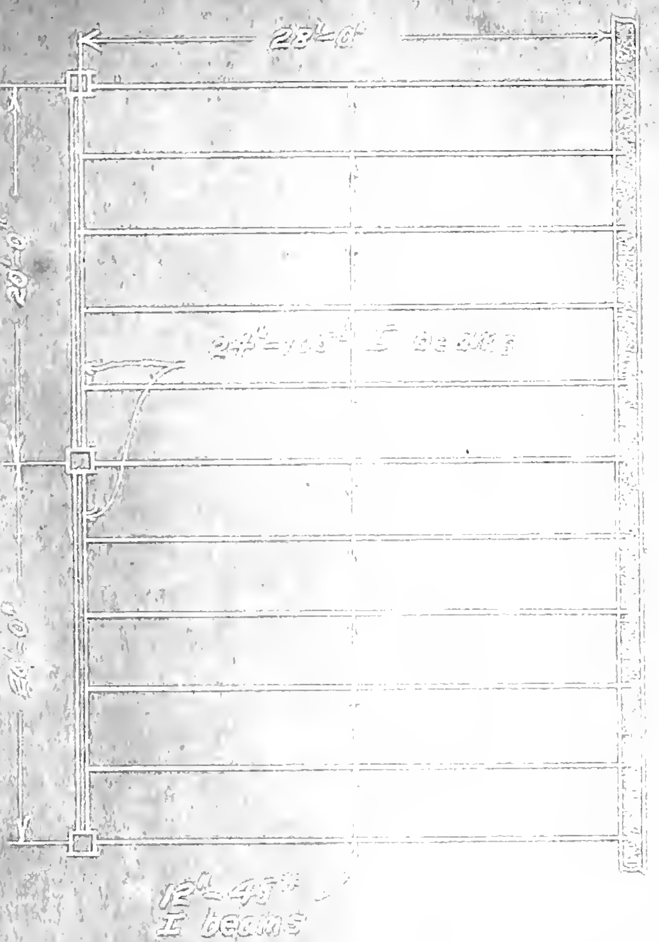
$2\ fL = 2\ \ x\ 25\ x\ .167 = 26.5$ ohms per wire.

The condensive reactance is

$$\frac{1}{2\pi fc} = \frac{1}{2\ \ x25x13.3x\ 10\ \ x75} = 6360 \text{ ohms.}$$

By constructing the regulation diagram the above values give 16 % for regulation at full non-inductive load and 15.8% for regulation for full load current 80% lagging power factor.

PLAN OF GALLERY FLOOR



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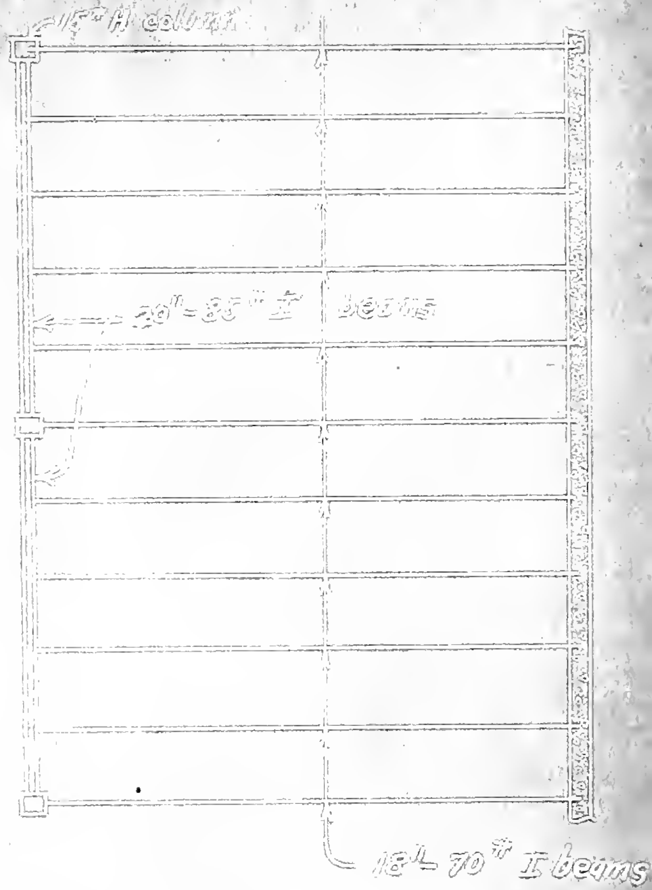

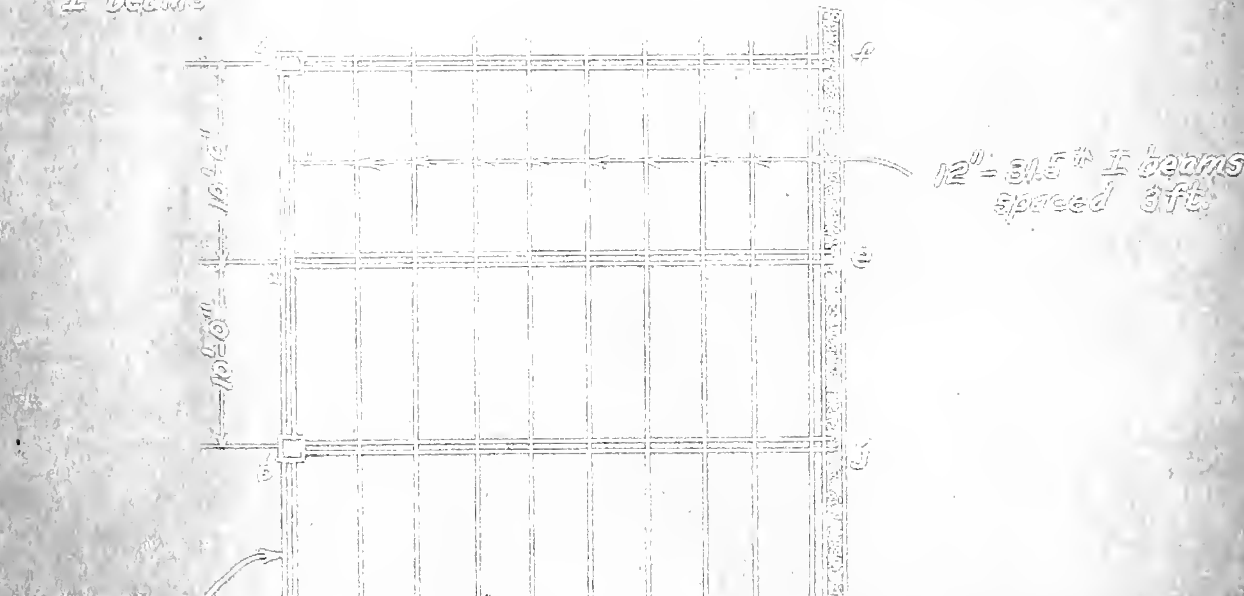

PLAN OF TRANSFORMER FLOOR

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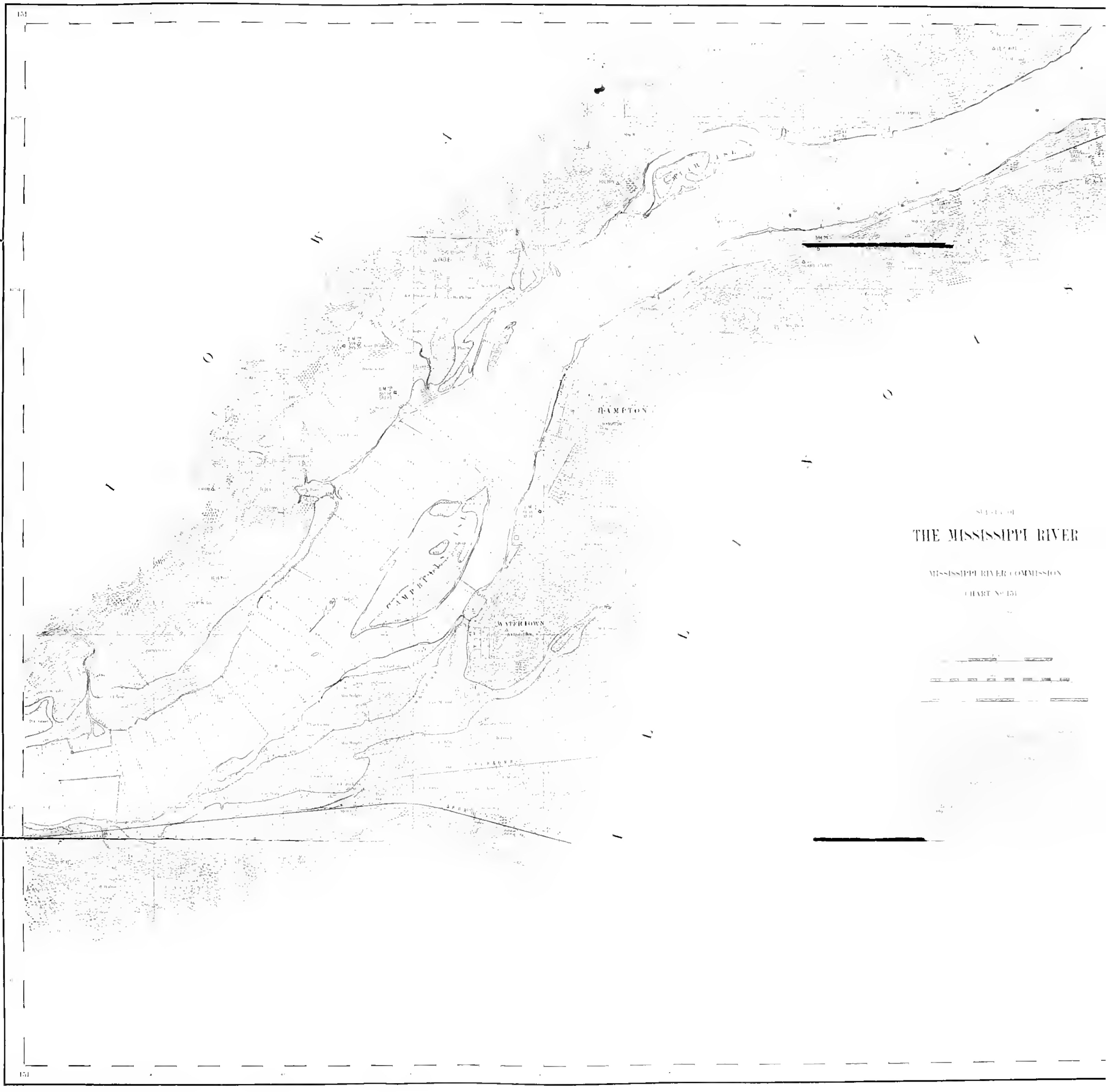
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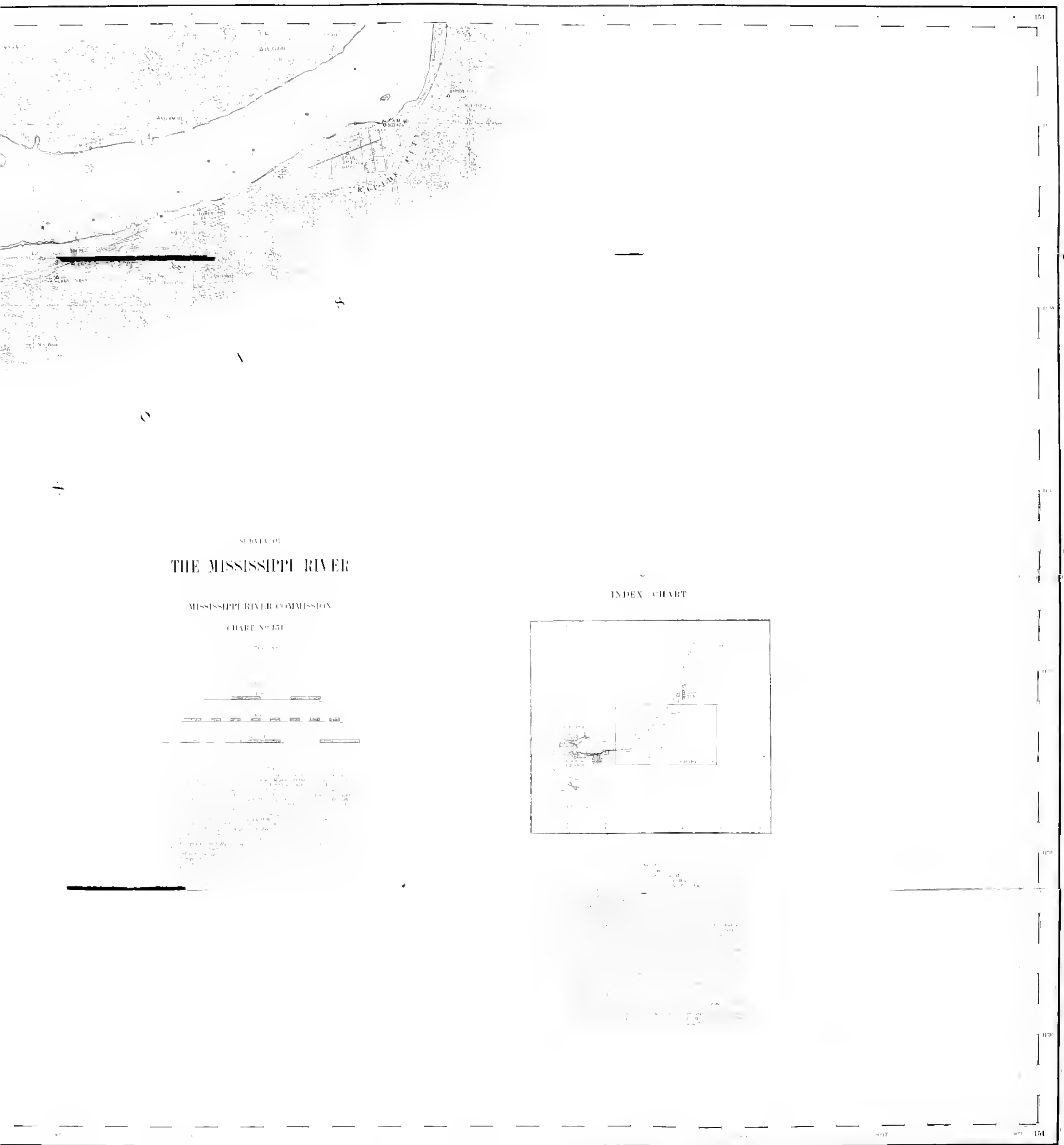
MISSISSIPPI RIVER COMMISSION
CAMPBELLS ISL.
WATERTOWN
HAMPTON



SURVEY OF
THE MISSISSIPPI RIVER
MISSISSIPPI RIVER COMMISSION
CHART No. 151
INDEX CHART
151

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